Radio frequency emissions evaluation for a 3D long range radar

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Abstract

Because of its high transmitted power, a long range surveillance radar system is a critical item concerning safety above all in public opinion. In its effort towards quality and customer’s satisfaction, AMS has developed a model of radiation which, starting from project simulation of the antenna pattern, allows one to calculate the average power density at any distance from the system, thus allowing one to determine possible clearances (minimum distances from buildings or protected areas) or helping in the selection of radar sites. Keywords: radio frequency, microwave, emission, evaluation.

1 Introduction

Radio Frequency and Micro Wave devices are widely spread today and the effect of EM radiation is a concerning issue which involves mobile phones, TV antennae and other communication systems. Safety related aspects are growing in importance even in contractual requirements, as customers ask contractors for a great effort in system safety and hazard analysis. This is true in particular for a surveillance radar system since it is required to transmit a very high power to achieve full performance for coverage distances of up to 500km.

For AMS great attention to this matter comes from its past tradition (as Selenia) about research in Electromagnetic Compatibility (EMC).

The AMS RAT-31DL system is an advanced D-Band, solid state phased array 3D surveillance radar whose features represent the state of the art in long range radar technology: multiple independent pencil beams, pulse compression and a monopulse technique allow very good range accuracy and resolution in the whole coverage volume. Radar antenna can be mechanically tilted to reach
greater heights for long range surveillance. Azimuth scanning is achieved with rotation, electronic beam steering is accomplished only in the elevation plane.

It is going to be installed in several NATO countries and it is already in service in Austria, Denmark, Turkey and Malaysia.

![RAT-31DL radar system](image)

**Figure 1:** RAT-31DL radar system.

## 2 Limitations to exposure

National authorities have adopted directives and laws to protect people from the effects of exposure to EM radiations, taking into account the scientific contribution of international and national institutions like ICNIRP (International Commission for Non-Ionising Radiation Protection) [6] or CEI (Comitato Elettrotecnico Italiano) [7]. The common scientific base is that the exposure to electromagnetic radiations causes a variation of the electrical features of human tissues and an increase of internal temperature; this variation is limited by the internal thermo-regulation system, which reacts in the same way for passive or active warming. Usually it has a reaction time of about six minutes, so the exposure to an EM field takes its effect on body temperature in the first six minutes and then a balance is reached with a temperature usually higher than the physiological one. The human body’s internal defence is not able to stand this over a prolonged exposure, which could therefore have hazardous consequences.
The common approach is to impose a limit to radiated field amplitude (or power density) with an average value (MPE, Maximum Permissible Exposure), where the average has to be intended over a six minute time interval and the vertical section of the human body.

The MPE level has been chosen equal to 0.1W/m², as it is a more restrictive value than those proposed in the relevant European directives [3] and recommendations [4]. It can be found in the Italian law [5] as a quality objective for emission from fixed TV and radio communication systems and relates to buildings where people are supposed to stay for more than four hours.

2.1 Exposure to pulsed fields

Existing regulations do not seem to fit systems that transmit very short high power pulses. A more suitable approach is the one proposed in [2]: to the usual time average it adds a further condition on the peak energy density which results in a limit on the peak power density. The standard suggests that in any 100ms period the peak energy density should be lower than a fifth of the energy density in the average time, i.e.

\[
\sum MPE_{PEAK} \times t_P = \frac{MPE \times T_{AV}}{5}.
\]

Eqn (1) allows one to calculate an MPE level for peak power density; of course it depends on the average MPE. About the other parameters, \( t_P \) is the pulse length and \( T_{AV} \) is the averaging time, i.e. six minutes.

The average over the vertical section of the human body can be performed by means of a “virtual measurement”, calculating ten values at least from ground level up to two meters in height and then averaging the obtained values. This average will be performed for peak values too, as we are interested in human body absorption, so the average peak value will be compared with \( MPE_{PEAK} \).

3 Evaluation

3.1 Assumptions

An array can be modelled as an M by N matrix of half wavelength dipoles. This assumption allows one to express the radiated field of the single dipole with the far field formulation [1] even for small distances, compared with array dimensions.

In this way the point value of the (array) radiated field is calculated as the combination of the dipole contributions in that point. It can also be assumed that the antenna radiates only in one half space. It means that the half space containing a given direction is radiated for half a turn only, thus allowing one to perform the time average, taking into account antenna rotation, simply halving the azimuth-average calculated values. To achieve significant results, the sum in eqn (1) has to be intended as over the number of pulses contained in every
100ms period in a given direction during the averaging time. This yields (for
typical values of the parameters) a $MPE_{PEAK}$ value of 30W/m$^2$.

The reference system (fig. 2) used is centred in the antenna centre and with
the z axis parallel to the longer side of the array; the x-z plane is supposed to be
parallel to the ground. This means that if the antenna is not mechanically tilted,
the planar array lays in the z-y plane, thus the x axis corresponding to the bore-
sight direction.

3.2 Proposed scenarios

A surveillance radar is usually installed in elevated sites, or on top of a tower
(covered with a radome). Two situations are of great interest: the vicinity of the
radar (platform) and the surrounding zones. To evaluate these two cases, the
height of –7m and –28m have been selected, representing radar building and
ground level; different ranges have been considered too, as the first hypothesis is
significant within a few meters, the second within some kilometres.

![Figure 2: Definition of the reference system in use.](image)

3.3 Results

Figures 3 and 4 show the Average Power Density as a function of distance for
the two described scenarios. In both pictures the straight line at $10^{-1}$ W/m$^2$
represents the MPE.

The curves are calculated for several values of beam steering angles, in
particular the lowest four are considered; they are listed in the legend in crescent
order. In particular, $\phi_1$ has a negative value and $\phi_2$ is slightly positive. The $\phi_1$
curve reaches its peak where the pointing direction crosses the plane $y = -7$. The
more the pointing angle increases, the more “side lobe” effects are involved at short distances since an always decreasing energy is directed into the \( y < 0 \) half space.

Figure 3: Simulation results for Scenario 1 (7m below antenna centre).

Figure 4: Simulation results for Scenario 2 (28m below antenna centre).
As far as distance increases in both cases test points start entering the $\varphi_2$ main beam: in the first scenario it happens at about 500m, in the second at about 2000m. However the MPE limit is always respected in scenario 2, while the overcoming in scenario 1 can be helpful while selecting a possible radar location or a clearance area.

The particular behaviour of the $\varphi_3$ curve in figure 4 is due to the fact that at that distance the test points fall between the main lobe and the first side lobe in elevation.

Further information comes from peak MPE analysis (figures 5 – 7): as long as the main beam is directed downwards a great amount of energy is measured. It should be considered on the other hand that this situation is meaningless since an air surveillance radar will not be pointed downwards unless it is located in a very high site (e.g. mountains).

In terms of safety, this analysis shows that the surroundings of a surveillance radar are not exposed to hazardous electromagnetic fields, as most of energy is not directed to the ground.

Personnel safety is achieved as well in the areas of the radar building which can be usually accessed during system operation. Both software and hardware means are usually provided to inhibit radiation when personnel are in the radome area or working on antenna for maintenance purposes.

![Figure 5: Peak values for scenario 1.](image-url)
Figure 6: Peak values for scenario 2.

Figure 7: Peak values for scenario 2 (zoom in).
4 Conclusions

The peculiar nature of radar emissions requires one to establish a limit also on peak power (or energy) to take into account the short, high power pulses being transmitted. Limits have been set via a combination of the requirements in [2] and [5], resulting in a generally more restrictive situation, nevertheless the examined radar system shows good compliance with applied standards on general public safety because of its mission nature (air surveillance) and the effort to incorporate safety principles (for personnel) into system design.

References